International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Piston Failure Analysis on Four-Wheeled 1000cc Engine Cylinder Capacity

Ahmad Zayadi, Novi Azman, Cahyono Heri Prasetyo, Sungkono

Abstract*: Pistons are one of the main components of a 1000 cc engine that functions as a pressure suppressor and a recipient of pressure combustion in the combustion chamber. In the examination of the 1000 cc sedan engine that has been operating for 30,000 hours found a rough sound on the engine and experienced loss compression on the cylinder block number 2. The purpose of the study was to obtain the factors causing the deformation of the piston 1000 cc sedan vehicles. The research method used is metallographic observation using ASTM E 3 and ASTM E 112, testing hardness using ASTM E 92 and SNI 19-0409-1989 and testing chemical composition using ASTM A 751. The results of research on piston damage can be seen that observation macrostructure proves that there is plastic deformation on the surface area of the piston material, the results of microstructure observation are known to occur microcrack on the top surface of the right side of the piston, there is no change in microhardness between the piston material in the deformed area with the deformed piston material hardness, piston material made of alloy Al-Si. In the area of the piston surface that experiences deformation, Mg2Si and Mg2Al3 compounds are formed, these compounds which cause microcrack on the piston's upper surface. Plastic deformation on the piston surface occurs due to a collision between the piston surface and the cylinder head due to the buildup of crust on the piston surface.

***Keywords*: piston, deformation, metallography, hardness, chemical composition.**

I. INTRODUCTION

Four-wheeled vehicles with 1000 cc engine cylinder capacity are the types of vehicles that are in great demand by the Indonesian people, especially those who live in big cities, like Jakarta with high levels of traffic congestion. This is because the car is environmentally friendly, fuel-efficient, and has a compact and lightweight design. Engine with a cylinder capacity of 1000 cc has 3 (three) cylinders that use a rotating angle of 120° so that the rotation is balanced. Although the 3-cylinder engine rotation can compensate for each other, combustion still causes vibrations. This is because there are no opposing cylinders that balance, as in the 4-cylinder engine. The piston is an important component in a 1000 cc engine with 3 cylinders a piston. The piston functions as a pressure inlet air and pressure receiver for combustion in the combustion chamber. The piston is connected to the

crankshaft through the piston rod (connecting rod) which will produce a 4-step performance in combustion on a 4 stroke engine, namely the suction step, the compression step, the effort step, and the exhaust step. In general, car engines need regular maintenance every multiple of 10,000 hours to maintain normal engine performance. Besides routine maintenance is also useful to anticipate if there is interference with engine components that can interfere with engine performance.

In the maintenance process carried out, it was found that there were symptoms of damage to the piston which is marked by the presence of rough noise on the engine due to piston performance is not optimal. At the time of the inspection process heard a rough sound on the engine found a loss compression on cylinder number 2. The results of the measurement of compression pressure on cylinder no. 2 are below the normal limit of 6 Psi while the normal limit of compression pressure is 11.5 Psi. On cylinder no. 1 and no. 3, the compression pressure is 11.5 Psi so cylinder no. 1 and 3 there is no loss compression. From the results of examinations on cylinder number 2, loss compression is thought to be due to a deformed piston surface. The deformed piston only operates for 30,000 hours while the normal operation of the piston is 200,000 hours. The piston cannot be used anymore and must be replaced with a new piston. The purpose of this study was to obtain the factors causing the failure of a piston of four-wheeled vehicles with a capacity of 1000 cc which occurred for 30,000 hours. Factors causing these failures can be identified by conducting tests which include: Metallographic observations to determine macrostructure and microstructure of piston material that has failed. Hardness testing to determine the hardness of the piston material that has failed. Chemical composition testing to determine the chemical composition of piston material that has failed [1]-[3].

II. RESEARCH METHODOLOGY

The flow diagram of the research implementation process can be seen in the Fig. 1. The process starts from checking defective pistons based on visual inspection. After the piston is obtained, the sample location of the piston failure is selected.

Manuscript published on November 30, 2019.
*Correspondence Author
Ahmad Zayadi*, Mechanical Engineering, Universitas Nasional, South Jakarta, Indonesia. Email: zayadi@civitas.unas.ac.id
Novi Azman, Electrical Engineering, Universitas Nasional, South Jakarta, Indonesia. Email: novi.azman@civitas.unas.ac.id
Cahyono Heri Prasetyo, Mechanical Engineering, Universitas Nasional, South Jakarta, Indonesia.
Sungkono, Mechanical Engineering, Universitas Nasional, South Jakarta, Indonesia.

The sample is then tested. There are three tests conducted, metallography, hardness, and chemical composition [4]. From the test data, an analysis is carried out and conclusions drawn from this study.

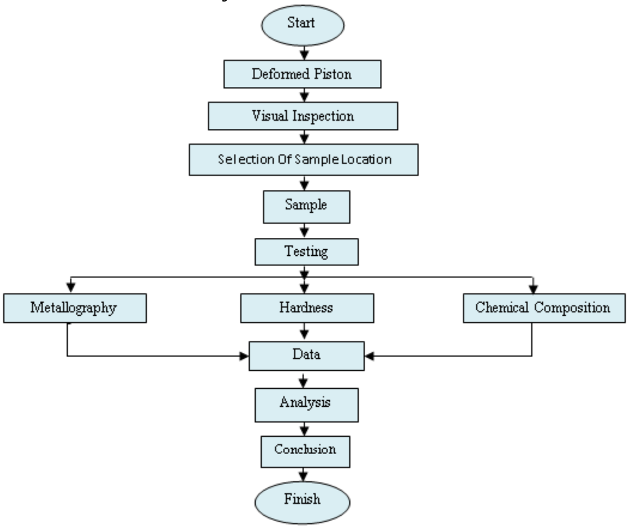

Fig. 1.Flow chart of failure analysis of pistons for 1000 cc four-wheeled vehicles

This research uses a piston from a four-wheeled car that has a 1000 cc engine cylinder capacity. Specifically, this is a type of sedan with a 1000 cc engine cylinder capacity.

III. RESULT AND DISCUSSION

Research conducted on the failure of pistons on four-wheeled vehicles with a capacity of 1000 cc was carried out through several stages, namely the measurement of test object dimensions, visual inspection, macrostructure, microstructure, hardness testing, and chemical composition testing. The testing activity was carried out in B2TKS BPPT in the PUSPIPTEK area, South Tangerang.

A. Macrostructure

Macrostructure testing is carried out on the damaged area to see the surface of a four-wheel piston capacity of 1000 cc. The examination was carried out with a 12x and 25x magnification stereo microscope, Fig. 2.

Fig. 2.Deformed Piston on 1000cc engine capacity sedan

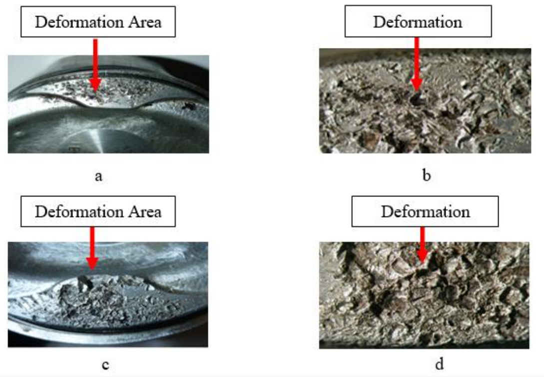

Fig. 3.Macrostructure of the piston upper surface is deformed

Fig. 3 shows the deformation on the surface of the left and right sides of the piston. Deformation on the top surface of the piston is thought to be due to a collision with the cylinder head caused by a buildup of scale on the piston top.

Caption:

a. Areas of the left side of the piston surface that are deformed.

b. Areas of the left side of the piston surface that are deformed. (Zoom: 25x)

c. The area of the right side of the piston surface deformed.

d. The area of the right side of the piston surface deformed. (Zoom: 25x)

Damage that occurs at the top (side of the combustion chamber) in the form of defects due to the impact of the piston with the cylinder head that causes deformation of the piston material [5]. Also, on the surface of the piston visible black crust that is thick enough to stick to the piston surface. The damage can cause defects in the piston which is thought to result in rough engine noise and loss compression.

B. Microstructure

Microstructure testing is carried out on pistons that are damaged, the results can be seen in figure 4.

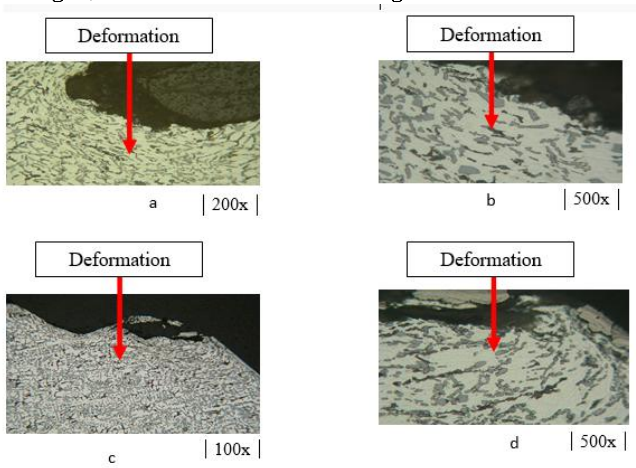

Fig. 4.Surface microstructure of a 1000 cc piston sedan

Caption of Fig. 4 are (a) a and b microstructure test results of the left side of the upper surface of the piston material (b) c and d of the microstructure test results of the right side of the upper surface of the piston material Figure 4.

Shows the elongated piston sample cut that has a defect due to a large impact load. This is supported by structural deformation. In the deformation area of the right side of the piston surface, the hardest impact occurs and is expected to cause cracks in that area [6], [7]. Whereas in the deformation area of the left side of the piston surface only small deformations occur that do not cause crack.
The occurrence of small cracks or microcrack in the deformation area of the right side of the piston surface can be seen in Fig. 5.

Fig. 5 provides information that there is a sharp defect that forms an angle that is indicated to hit an object that is sharp enough. In the area of impact found a fine crack or microcracks.

The fine cracks form a cavity or hollow which has an impact on the performance of the piston decreases, causing an effect on the engine in the form of symptoms of loss compression and noise.

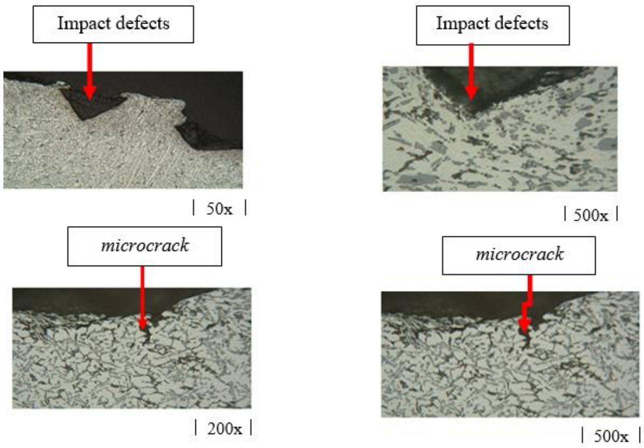

Fig. 5.Defects on the piston (etching: 50x, 100x, 200x, and 500x magnification)

Microstructure testing is also carried out in the nearest area around the area where deformation occurs in the piston material. The test results can be seen in Fig. 6.

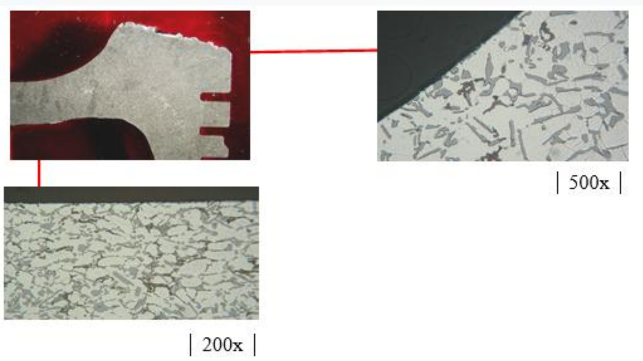

Fig. 6.The Closest Area to the Deformation Area (etching: Dix's Keller reagent)

Figure 6 provides information that the concave surface area (middle of the piston) on the upper side piston closest to the deformed piston area does not reveal any defects. This shows that there was no collision between the cylinder head and the piston in the area caused by the buildup of scale. From the explanation of the results of microstructure testing, 3 conclusions can be drawn [8], [9], namely:

1. The left side area of the top surface of the piston occurs deformation but does not cause cracks/cracks.
2. Concave side area (middle) of the top surface of the piston does not occur deformation because there is no collision between the piston with the cylinder head caused by the crust.
3. The right side area of the top surface of the piston occurs very large deformations that cause fine cracking/microcrack, this occurs because the most accumulation of crust is on the right side area of the piston surface. A large amount of scale accumulation in the right side of the piston surface is due to the area being close to the exhaust valve so that the scale tends to accumulate in the area.

C. Hardness

Piston hardness testing is carried out at 2 (two) locations, namely the damaged piston and the undamaged piston. Hardness testing in each sample of 15 sample points of the hardness test location is shown in Fig. 7, while hardness test data is shown in Table 1.

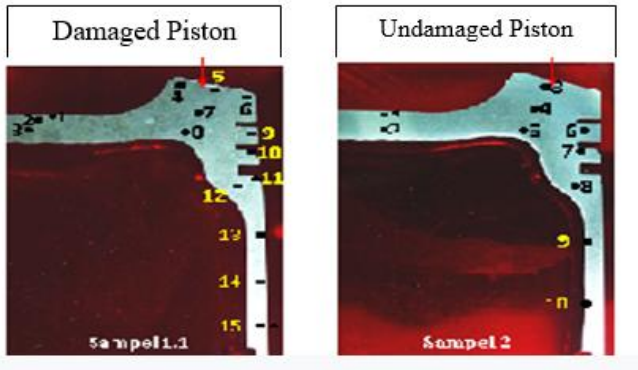

Fig. 7.Piston Material Hardness Test Point Location

Fig. 7. Shows the location of a sample of hardness tested. Sample 1 (piston that was failure there were 15 points of hardness test location and sample 2 (piston that did not suffer) there were 10 points of hardness test location.

Table- I: Piston material hardness test values

Location	No.	Vickers Hardness Rate (HV)	
		Piston 1 (Failure)	**Piston 2 (Unfailure)**
Piston Mains Area	1	127	126
	2	126	125
	3	125	129
Deformation area	4	127	128
	5	125	128
	6	123	125
The closest area of deformation	7	129	127
	8	130	128
	9	128	127
	10	134	128
	11	131	-
The furthest area of deformation	12	107	-
	13	126	-
	14	127	-
	15	126	-
Average		126	127

Table-I. Shows that the average hardness of the deformed piston material is 126 HV and the average hardness of the deformed piston material is
127 HV.

From the violence side, it is found that there is no difference in the hardness of the material around the defect with the piston base material. This shows that deformation that occurs on the piston surface does not have an impact on the change in material hardness of the piston itself. Deformation that occurs on the top surface of the piston causes microcarck by the results of microstructure testing. The presence of a microcrack on the top surface of the piston can cause a rough noise in the engine that is sourced from the fluid pressure in the form of air in the combustion chamber decreases (failure in the adiabatic area) which causes the compression stroke to become unstable.

The impact of the instability of the compression step is the occurrence of loss compression which will result in incomplete combustion resulting in a pile of soot crust leftover from the combustion chamber and stacked on the piston surface [10], [11]. Thus the handling carried out to repair the problem is to replace a new piston.

D. Chemical Composition

Testing the chemical composition of the piston material is carried out using a spectrometer to determine the constituent elements of the piston material. Test data for the chemical composition of piston materials are shown in Table-II. The content of the main combination of piston material is 81.10% Al and 14.851% Si with other combined elements is 0.533% Fe and 0.938% Mg. Based on the composition of the combined elements it is known that the piston material is made of Al-Si alloy.

Table- II: Data on the chemical composition of pistons that have defects

No	Element	Deformed piston	Piston that is not deformed
		Element Content (% by weight)	Element Content (% by weight)
1	Al	81.10	81.15
2	Fe	0.533	0.542
3	Si	14.851	14.943
4	Mn	0.051	0.052
5	Mg	0.938	0,944
6	Cr	0.012	0,013
7	Ni	1.034	1.032
8	Cu	1.138	1.137
9	V	0.011	0.012
10	Ti	0.024	0.025
11	Sn	0.544	0.554
12	Pb	0.001	0.001
13	Co	0.007	0.008
14	Zn	0.000	0.000

From Table-II it is known that for deformed pistons there was a decrease in the Al element content by 0.05%, the Fe element content by 0.009%, the Si element content by 0.092% and the Mg element content by 0.006%. This shows that the deformation that occurs in the piston material affects the interaction between the combining elements in the piston material so that the Mg_2Si and Mg_2Al_3 compounds will be formed. The formation of these compounds causes a voltage difference in the piston material component which results in residual stress [12]. The resulting residual stress causes the piston material area to experience fine cracks or microcrack. Over a long period, the cracks will corrode and the accumulation of excess scale and cracks in the cracks will result in decreased piston performance and the engine cannot work normally [13].

E. Piston Damage Analysis for Four-Wheeled Vehicles with a Capacity of 1000 cc

From the elaboration of the results of the analysis of piston material testing namely metallographic observations, hardness testing and chemical composition testing it can be seen that the damage to the piston is caused by a buildup of crust on the piston surface, so that the gap between the piston surface with the cylinder head becomes small when the piston is operating. The existence of the scale can cause a collision between the surface of the piston with the cylinder head. The collision occurs repeatedly so that it can cause plastic deformation on the piston surface. As the piston operating time goes on, the impact can cause fine cracks in the deformed piston area. The fine cracking is thought to be the cause of loss compression and rough noise on the engine.

IV. CONCLUSION AND SUGGESTION

Based on the results of a study of research data on piston damage in a 1000 cc four-wheeled vehicle, it can be concluded as follows.

1. Observation of the macro-structure proves that there is deformation in the surface area of the piston material.
2. Microstructure observation shows that the deformation area of the left side of the piston's top surface does not occur, the concave area or the center area of the piston's surface is not deformed/deformed and in the right side area there is a very large deformation resulting in a slight crack (microcrack) in the area.
3. There is no difference in the value of microhardness between the piston material in the deformed area and the hardness of the non-deformed piston material.
4. The 1000 cc sedan piston is made of AL-Si alloy. In the deformed piston surface area, Mg2Si and Mg2Al3 compounds are formed. These compounds that cause the occurrence of fine cracks (microcrack) on the top surface of the piston.
5. Early damage to the 1000 cc sedan piston material is caused by the presence of a microcrack on the surface material of the upper side of the piston due to the impact of the piston surface with the cylinder head.

Based on the results of research conducted on deformed pistons, the following are suggested.

1. Needed to do a deeper assessment of the size of fine cracks using a Scanning Electron Microscope (SEM).
2. The scale content that has accumulated on the piston top surface needs to be known by using SEM and EDAX.

3. Vehicle maintenance must be done periodically to prevent premature damage to the piston of four-wheeled vehicles with a capacity of 1000 cc.

REFERENCES

1. Nurhadi. 2010. Study of piston material characteristics and development of prototype based piston used piston waste. Thesis. Mechanical Engineering Masters Degree Program Diponegoro University Semarang.
2. Wahyu, B, U. 2008. Effect of addition of strontium and phosphor modifiers and heat treatment processes on the mechanical properties and microstructure of AC8H aluminum for piston products. Thesis. Faculty of engineering, metallurgy and material study programs of Indonesian universities. Depok.
3. Hasiolan, P. 2003. Analysis of Piston Material Quality in Chinese Motorcycle Products and Japanese Products. Thesis. Mechanical Engineering. National University.
4. ASTM Standards, 2003, Metal Test Methods and Analytical Procedures, volume 03.01, West Conshohocken United States.
5. Duskiardi, T, S., 2002, Effect of Pressure and Temperature of Die Squeeze Casting Process on Hardness and Micro Structure in Local Commercial Piston Materials, Journal of Mechanical Engineering Vol. 4 No. April 1, 2002, Petra Christian University Surabaya, pp. 1-5.
6. ASTM. Metals Test Methods and Analytical Procedures, 2002, Vol 03.01.West Chonshohocken. ASTM International.
7. ASM International, 1993, ASM Specialty Handbook: Aluminum and Aluminum Alloys, Ohio.
8. Surdia, Tata & Saito, Shinroku. 1992. Knowledge of Technical Materials. (Second edition). Jakarta: Pradnya Paramita.
9. American Society Of Materials, 1990, Handbook Vol 13, Corrosion.
10. Anonymous, 1000 cc Mechanical Engineering Repair and Information Handbook, PT ASTRA DAIHATSU MOTOR TECHNICAL SERVICE DIVISION,
11. Anonymous, BASIC 1 PSG DAY RELEASE, Astra International Training Center.
12. Anonymous, Textbook of PTM307 Energy Conversion Machine.
13. Doehler, H., Die Casting, McGraw Hill Book Company, New York.G. O. Young, “Synthetic structure of industrial plastics (Book style with paper title and editor),” in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.